CHAPTER 3

DESIGN PHILOSOPHY

Chapter 3 Design Philosophy
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3.1 Introduction

3.1.1 Purpose

ADOT Policies for Highway Drainage are presented in Chapter 600 of the Roadway Design Guidelines. The purpose of this chapter is to outline design philosophies that guide and determine the multitude of variables that influence drainage design. The following sections of this chapter will present information concerning hydraulic design of drainage structures and related Federal and ADOT policies.

3.1.2 Policy vs. Criteria

Policy and criteria statements are closely related - criteria being the numerical or specific guidance that is founded in broad policy statements. For this manual, the following definitions of policy and criteria will be used:

Policy - is a definite course of action or method of action, selected to guide and determine present and future decisions.

> Following is an example of a policy statement:
> "The designer will size the drainage structure to accommodate a flood compatible with the projected traffic volumes."

Design Criteria - are the standards by which a policy is carried out or placed in action.

> The design criteria for designing the structure might be:
> "For projected traffic volumes less than or equal to 750 vehicles per day, drainage structures shall be designed for a 10-year flood (exceedence probability - 10%). For projected traffic volumes greater than 750 vehicles per day, a drainage structure shall be designed for a 25-year flood (exceedence probability - 4%)."

Policy statements describe the goal, design criteria provides the measurement for determining if the goal is achieved.

3.2 General Hydraulic Design Philosophy

3.2.1 Introduction

An “adequate” drainage structure may be defined as one that meets the following policies:

- the design of the structure meets or exceeds ADOT standard engineering practice, and
- the design is consistent with what a reasonably competent and prudent designer would do under similar circumstances.

3.2 General Hydraulic Design Philosophy (continued)

3.2.1 Introduction (continued)

General Policies

In determining an “adequate” drainage structure, the following points are made in regard to the design process.:

- It is the designer's responsibility to provide an adequate drainage structure for the design conditions established. The designer is not required to provide a structure that will handle all conceivable flood flows under all possible site conditions.
- The detail of design studies should be commensurate with the risk associated with the encroachment and with other economic, engineering, social, or environmental concerns.
- The design flood event serves as criteria for evaluating the adequacy of a proposed design. The "design flood" is the recurrence interval of the flood for which the drainage structure is sized to satisfy the varied criteria determined applicable.
- The predicted value of the base (100-year) flood serves as the present engineering standard for evaluating flood hazards and as the basis for regulating floodplains under the National Flood Insurance Program
- It is standard engineering practice to use the predicted value of the 100-year flood as the basis for evaluating flood hazards; however, flows larger than this value may be considered for complex, high risk or unusual cases that require special studies or risk analyses.
- The developed hydraulic performance of a drainage structure depicts the relationship between floodwater stage (or elevation) and flood flow magnitudes. For drainage facilities that affect developed properties, the performance data should include the 100-year flood. With the performance data, the designer can evaluate the adequacy of the design.

The design process usually has several phases: concept development, preliminary design, and final design. For the design of many drainage structures these phases are rapidly stepped through, especially for experienced designers. In working thorough the phases the studies listed below are normally conducted as a part of the design of highway drainage structures and serve as a means of achieving an “adequate” drainage design:

- hydrologic analysis,
- hydraulic analysis, and
- engineering evaluation of developed alternatives.

These studies are discussed further in the following sections.

3.2 General Hydraulic Design Philosophy (continued)

3.2.2 Hydrologic Analysis

The initial step is to determine the hydraulic loading, i.e., the flood flow to be accommodated. The designer must ascertain the magnitude of the flood flow using the methods and judgments appropriate for the situation under consideration. ADOT hydrology methods and practices are described in the ADOT Hydrology Manual.

3.2.3 Hydraulic Analysis

The next step in the design process involves preliminary selections of alternative designs that are judged to meet the site conditions and to accommodate the flood flows selected for analysis. The hydraulic analysis is made utilizing appropriate formulas, physical models or computer programs for purposes of defining, calibrating and checking the performance of the preliminary designs for the range of flows to be considered.

3.2.4 Engineering Evaluation

The final step in the design process is the engineering evaluation of the preliminary designs and selection of the final design. Engineering evaluation is the approach followed in defining, evaluating, and selecting a final design. This process involves consideration and balancing of a number of factors. Some of these factors are:

- effectiveness in achieving desired results,
- costs including construction and maintenance,
- legal considerations,
- flood hazards to highway users and neighboring property owners,
- environmental and social concerns, and
- other site specific concerns.

3.3 Coordination

3.3.1 Interagency Coordination

The Arizona Department of Transportation (ADOT) in the process of developing transportation facilities will traverse many watersheds; department coordination with responsible local agencies is essential to ensure that proposed facilities are compatible with the long-term plans for the area. Coordination between concerned agencies during the project planning phase will help produce a design that is more satisfactory to all. Discussions with the local floodplain administrator should identify local studies, concerns, and any partnership opportunities. Coordination may also be necessary with other State and Federal agencies. See Chapter 2 for the individual responsibility of Federal agencies.

3.3 Coordination

3.3.2 Intra-agency Coordination

Early planning and location studies are conducted by the Predesign Section of the Roadway Engineering Group. Drainage designs performed during the pre-design phase shall be coordinated with the Drainage Section so that duplication of effort is minimized and all those who might be involved in future project work will be informed of any ongoing studies and study results.

3.4 Stormwater Management Plan

3.4.1 Introduction

During the concept development phase, a stormwater management plan should be developed that adequately address project goals. The storm water management plan should specifically identify the criteria of the many elements that are to be considered in achieving a design that meets or exceeds the required and/or desired performance.

For the areas under consideration the following questions must be addressed:

- What is the impact of the facility on the existing conditions?
- What is the impact of the existing condition on the facility?

The elements that are to be addressed are discussed below.

3.4.2 Quantity

Determinations of stormwater quantity are necessary for evaluating the impact of a project. The methods discussed in the ADOT Hydrology manual are to be used to determine the magnitude of discharges to be evaluated.

3.4.3 Flood Hazards

Floodflow characteristics at a highway stream crossing should be carefully analyzed to determine their effect upon the highway as well as to evaluate the effects of the highway upon the floodflow. It is important to identify flood hazards prior to any highway involvement to determine how the flood hazard will be affected with the proposed highway project. Flood hazards should include effects to private property both upstream and downstream (i.e., changes to flooding such as overtopping floodwaters diverted onto previously unaffected property). The impacts of any proposed action must be understood before the final selection is made of the recommended alternative. The number one goal in dealing with off-project flows is to perpetuate the natural drainage conditions.

3.4 Stormwater Management Plan (continued)

3.4.4 Floodplain Encroachment Considerations

A primary drainage consideration for facility sizing of a stream crossing is the evaluation of the impact of floodplain encroachments. Hydraulic and environmental considerations of highway river crossings and encroachments are presented in the FHWA Highways in the River Environment, Training and Design Manual (1990). The Manual provides examples of typical river environments and identifies possible local, upstream and downstream effects of highway encroachments.

The principal factors to be considered when designing a stream crossing that involves encroachment within a floodplain are:

- river type (straight or meandering),
- river characteristics (stable or unstable),
- river geometry and alignment,
- hydrology,
- hydraulics,
- floodplain flow,
- economic (land use and land ownership) considerations, and
- environmental considerations.

A detailed evaluation of these factors is part of the hydraulics study. Specific crossing components to be determined include:

- the geometry and length of the approaches to the crossing,
- the location of the longitudinal encroachment in the floodplain,
- the amount of allowable longitudinal encroachment into the main channel,
- the type and size of structure, bridge or culvert, and the means to ensure the stability of the structure against flood flows, and
- the required river training works to ensure that river flows approach the crossing or the encroachment in a complementary way.

3.4.5 Environmental Considerations

It is important to document the drainage considerations that affect the environment for the proposed project including all alternatives that will receive consideration. The identification of drainage impacts on environmental considerations early in the planning process can prevent major implementation problems as the project development proceeds.

3.4 Stormwater Management Plan (continued)

3.4.6 Water Quality

The two major sources of contaminants into surface waters are from soil erosion and deposition and from the deposited contaminants on the roadway surface. In general, erosion and sediment transport should be limited by developing and implementing an erosion and sediment control plan which addresses both temporary and permanent control practices. Information regarding temporary erosion and sediment control is provided in the **ADOT Erosion and Pollution Control Manual**. Background information is provided in the Erosion and Sediment Control Chapter of this manual. Permanent erosion control measures are presented in the energy dissipator and bank protection chapters.

Common impacts of excessive erosion include:
- Turbidity which reduces in-stream photosynthesis and results in reduced food supply and aquatic habitat,
- Introduction of soil nutrients into waters that cause algal blooms, which reduces water clarity and depletes oxygen,
- Sedimentation of stream bottoms that blankets fauna and destroys spawning areas, and
- Removal of top soil that leaves hard, rocky and infertile soil, which is difficult to revegetate.

Quantification of the levels of contaminants that are being washed off a roadway is complicated by the variable effects of and the periods between storm events. The contributory factors are rainfall intensity, roadway surface characteristics and particle size. The varying interaction of these factors makes it difficult to precisely estimate the impact that discharge will have on water quality. A listing and description of common contaminants found on roadways is presented in Appendix 3-A, Table 3-1. The table includes examples of the contaminants, the analytical determination for identifying them and their primary sources.

Several broad categories of degradation have been developed to delineate or describe levels of stormwater impacts:
- Aesthetic deterioration: Undesirable general appearance features (dirty, turbid, or cloudy) and actual physical features (odors, floating debris, oil films, scum, or slime) are present.
- Dissolved oxygen depletion: When the oxygen demand of bacteria is stimulated by the organics, the subsequent reduction in oxygen levels can disturb the balance between lower forms and the food chain. Unoxidized nitrogen compounds (ammonia) can also cause problems.
- Pathogen concentrations: High concentrations of several pathogens can reduce the acceptable uses of the receiving waters.
- Suspended solids: The physical buildup of solids can cover productive bottoms, be aesthetically objectionable and disrupt flow and navigation.
- Nutrients: Accelerated eutrophication that stimulates growth of aquatic vegetation can cause a water body to become aesthetically objectionable, deplete dissolved oxygen and decrease recreational value by creating odor and overgrowth. Advanced eutrophication can lead to sediment buildup, which reduces storage capabilities.

3.4 Stormwater Management Plan (continued)

3.4.6 Water Quality (continued)

- Toxicity: The two types of toxins generally found in stormwater (metals and pesticides/persistent organics) may build up in sensitive areas over the long term. At high levels, they can have serious shock effects on aquatic life. Low levels can become significant by accumulation up the flood chain.
- Hazardous spills: Depending on the characteristics of the spill, serious water quality problems can result.

3.4.7 Permits

Specific Federal and State drainage permits that will be needed for a highway project must be identified early in the planning stages. Prior to initiating design work, the designer must review the environmental document to identify regulatory commitments, constraints and any permits required. The permits required are usually:

- stormwater discharge permits, (NPDES)
- dredge and fill permits,(404)

3.4.8 Construction Considerations

Many serious construction problems arise because important drainage and water-related factors are over-looked or neglected in the planning and development phases of the project. Such problems include:

- soil erosion,
- sediment deposition,
- pollution of streams, lakes, and rivers,
- destruction of wildlife habitat,
- destruction of wetlands, and
- impairment of utility systems.

With proper planning, many problems can be avoided or cost effective solutions developed to minimize damages. Consideration of these possible problems is required during context-sensitive design development.

3.4.9 Maintenance Considerations

The stormwater management plan must recognize the need for erosion and sediment controls and provide a conceptual approach for managing the impacts. The maintenance requirements of possible alternatives must be evaluated. Experience in the area is the best indicator of maintenance problems and interviews with maintenance personnel could be extremely helpful in identifying maintenance concerns with potential designs. Reference to highway maintenance and flood reports, damage surveys, newspaper clippings and interviews with local residents could be helpful in evaluating potential maintenance problems.

3.5 State Policies

The applicable State policies regarding design criteria are presented in Chapter 600 of the ADOT Roadway Design Guidelines and in the ADOT Erosion and Pollution Control Manual.

Appendix A

Table 3-1
Listing of Common Stormwater Contaminants

Classification	Examples	Analytical Determination	Primary Sources
Particulates	Dust and dirt, stones, sand gravel, grain, glass, plastics, metals, fine residue	Settleable solids	Pavement, vehicle, atmosphere, litter, maintenance
Heavy metals	Lead, zinc, iron, copper, nickel, chromium, mercury	Specific heavy metal via atmospheric absorption	Vehicle, atmospheric fallout and washout
PCB, pesticides, herbicides	Chlorinated hydrocarbons, organic-phosphorous	Gas chromatography	Spraying of vegetation
Inorganic salts	$CaCl_2$, NaCl, SO_4, Br solids, conductivity	Cl, SO_4, Br, non volatile	Deicing salts, atmos-pheric washout, vehicle
Organic matter	Vegetation, dust and dirt, humus, roadway accumulations, oil, fuels	Volatile fraction hexane extractables (oil and grease), BOD, COD, TOC	Vehicular airborne fallout, vegetation, vehicle, litter, aerosols
Nutrients	Nitrogen, phosphorus	TKN, NO_2, NO_3, PO_4	Fertilizer
Pathogenic Bacteria (indicators)	Coliforms	TC, FC, FS and other specific indicators	Soil, litter, excreta, bird droppings
Other	Asbestos, rubber, special compounds	Chemical diffraction and electron microscopy, special techniques	Vehicle, specific additives